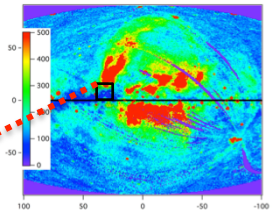
Where in the Milky Way is the North Polar Spur?

Rosine Lallement, Steven L. Snowden, K. Kuntz, Dimitra Koutroumpa, Isabelle Grenier, J.-M. Casandjian



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Snowden et al, 97

Where in the Milky Way is the North Polar Spur?

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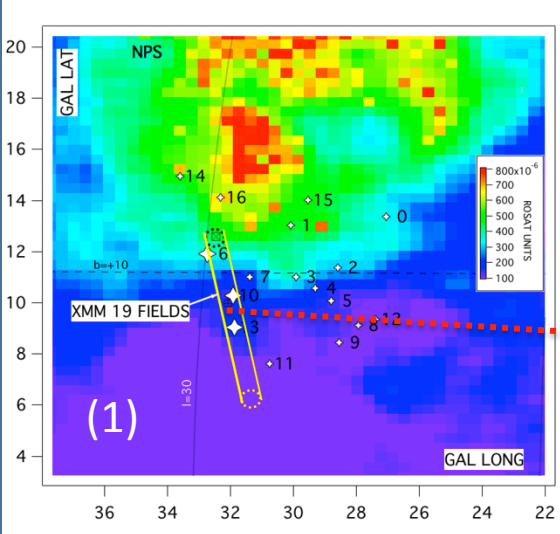
A series of pointed observations with XMM-Newton of the X-ray bright "North Polar Spur" (*) near l=30° and b=8° has been analyzed in combination with dedicated ground-based absorption measurements and three-dimensional reddening maps. There is compelling evidence that the southern terminus of the North Spur is absorption bounded and that the X-ray emitting region lies behind the Aquila Rift clouds, at least hundreds of parsecs away. Moreover, absorbing columns deduced from X-ray spectral fitting correlate more tightly with dust optical depths from Planck than with any other ISM column indicator, suggesting that the emission may originate several kpc away. This result raises the question of a possible link between the Spur and outflows from the inner Galaxy (Fermi bubbles, Galactic wind). (* P074189, P.I. K.D. Kuntz)

XMM observations of the southern terminus of the NPS



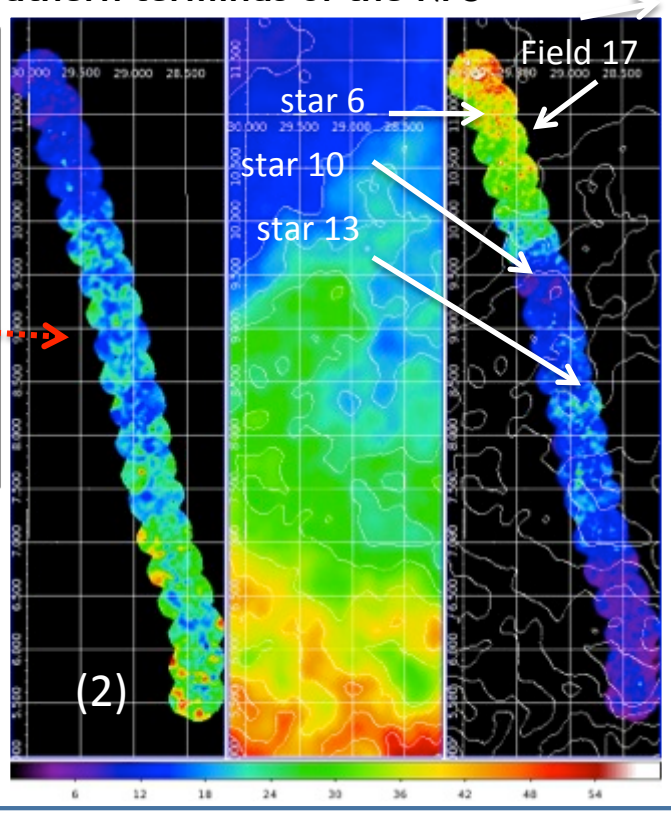


Fig1: XMM fields and observed nearby stars (✧)

Fig 2: Left:(0.75-1.3)/(0.4-0.75) keV hardness ratio; Center: IRAS 100 um data; Right:0.3-1.4keV

Absorbing columns deduced from spectral fitting

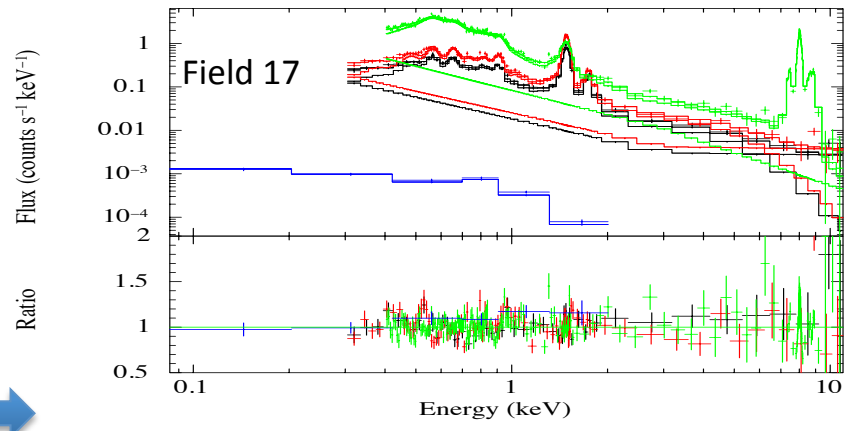


Fig 3:Example of model fit: MOS1(black)-MOS2(red)-PN(green) of field 17

Analysis: The 19x3 spectra were simultaneously fitted with the sum of:
-Unabsorbed foreground low temp gas: LHB kT=0.11keV
-Absorbed NPS kT=0.19 keV
-Absorbed bulge kT=0.75keV
-CXB power-law
Absorbing N(H)NPS and N(H)bulge and fluxes free to vary. LHB flux identical for all fields.

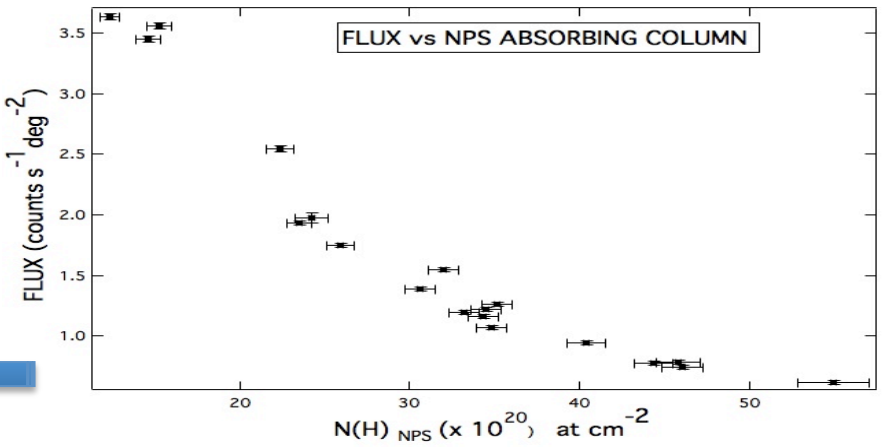


Fig 4: I(NPS) vs N(H) (NPS) from the simultaneous fit

Comparison with ISM distance-limited absorption data

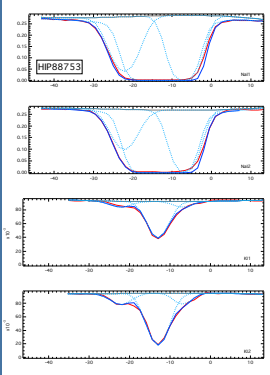


Fig 5a: Example of simultaneous NaI(5890-5896A)-KI(7665-7700A) absorption profile-fitting : star 5

Star	d(pc)	$N(H)_{KI}$	field	NH_{XMM}
6	135	3.1e19	18	1.5e21
10	279	4.1e20	13	3.4e21
13	344	1.7e21	10	2.3e21

3 stars along the XMM path

Optical spectra of nearby stars are fitted for NaI and KI. KI is used to estimate N(H) (Welty+01). For the 3 stars located along the XMM path NH(KI) <<NH(XMM).

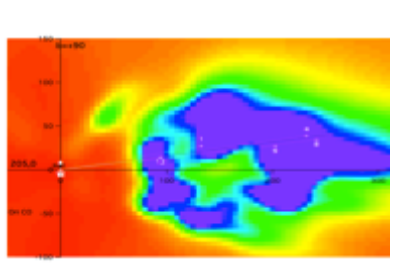


Fig 5b: Vertical cut in the 3D local dust map (Lallement+(14)) along l=25°. Density increases from red to violet. Integration between Sun and target stars is used to estimate E(B-V) in fig 5c.

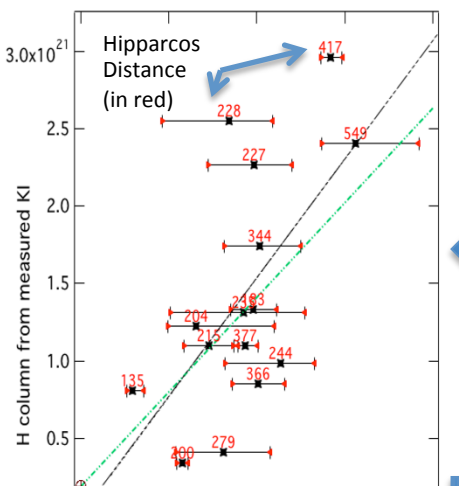


Fig 5c: map-integrated E(B-V) towards the 17 target stars and the KI-based N(H). The linear fit is close to the Gudennavar+12 value. This validates the use of the map to integrate along the nearby XMM FOVs.

CONCLUSIONS: 1) The exponential decrease of the fitted NPS flux as a function of the absorbing column as well as the correlation between the flux and the hardness ratio (not shown here) demonstrates that the NPS terminus is **absorption bounded.**

2) The comparison of the **XMM absorbing columns** with other IS column estimates: (i) specific absorption data towards nearby stars, (ii) local reddening maps, (iii) large-scale reddening maps, (iv) Planck dust emission, all together show compelling evidence for a source location **beyond 300pc, and potentially much farther away based on the excellent correlation with the total amount of dust traced by Planck.**

This strongly reinforces past and recent suggestions that the **NPS/ Loop1 structure seen in X-rays, radio, and γ's may has a link with the Fermi bubbles/ WMAP haze and other galactic center large scale** features (Sofue99, Bland-Hawthorn&Cohen03, Sarkar +15, Ursino+16..). In this case **high-latitude HI shells that are nearby** (Puspitarini-Lallement12) **are not directly related to NPS/Loop1 but coincidentally similarly located and shaped.**

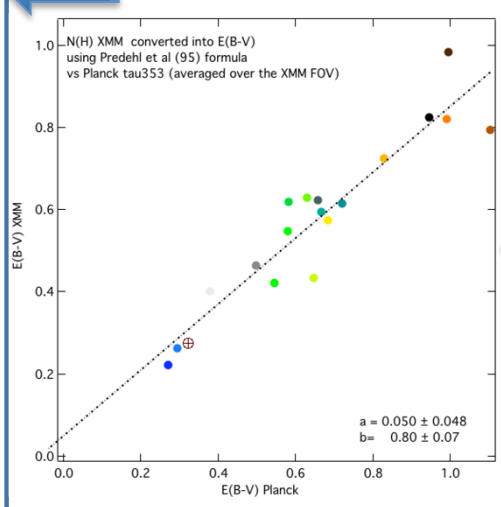


Fig 7: XMM absorbing column N(H) converted into color excess E(B-V) using Gudennanavar+ (12) formula vs Planck color excess based on the dust optical thickness τ-353GHz. From all color excess estimates Planck provides the best correlation with XMM absorbing columns.

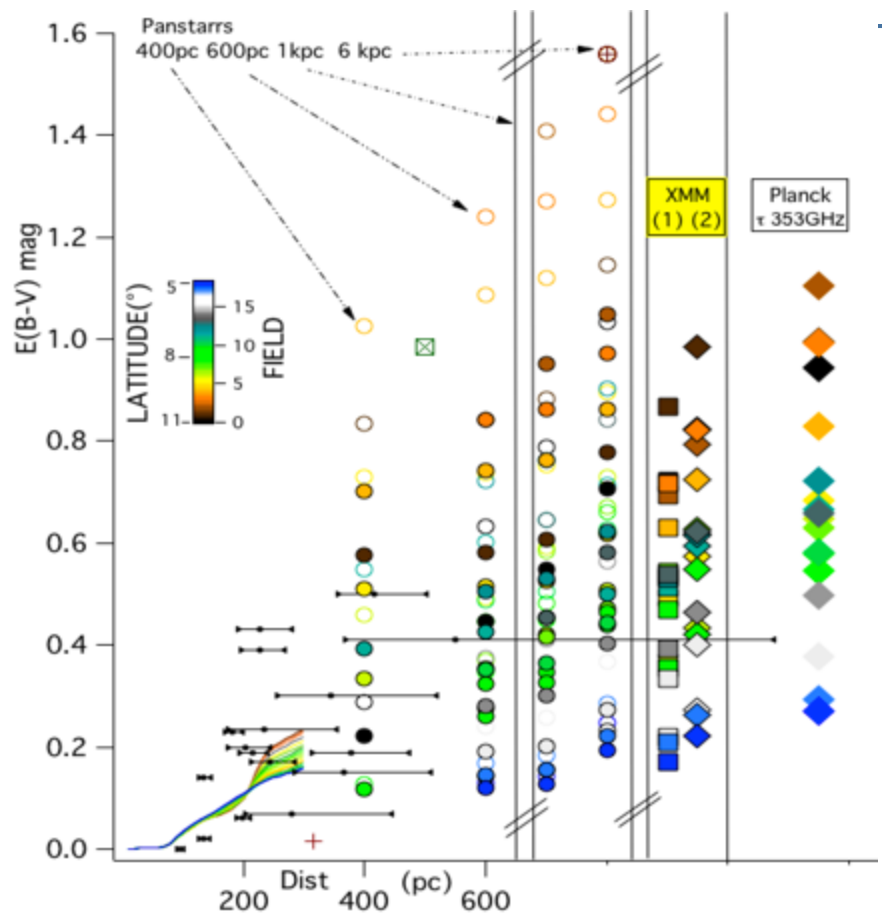


Fig 6:From right to left for the 19 fields: Planck τ-based E(B-V)s; XMM—based estimates for 2 N(H)=>E(B-V) conversions, Predehl +95 (1) and Gudennavar+12 (2); Panstarrs estimates for 4 distances (Green+15, circles) and their rescaled values using Bonifacio+00 formula (filled circles). Below 600pc are shown, as a function of dist, the E(B-Vs) integrated from 0 to 300pc in the local maps (solid lines) and the results for the program stars (fig1). A jump in reddening occurs between 300 and 400pc. XMM data correspond to post-jump values.